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Captured older stars as the reason for apparently prolonged star formation in young star clusters

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ABSTRACT
The existence of older stars within a young star cluster can be interpreted to imply that star formation occurs on time scales longer than a free-fall time of a pre-cluster cloud core. Here the idea is explored that these older stars are not related to the star formation process forming the young star cluster but rather that the orbits of older field stars are focused by the collapsing pre-cluster cloud core. Two effects appear: The focussing of stellar orbits leads to an enhancement of the density of field stars in the vicinity of the centre of the young star cluster. And due to the time-dependent potential of the forming cluster some of these stars can get bound gravitationally to the cluster. These stars exhibit similar kinematical properties as the newly formed stars and can not be distinguished from them on the basis of radial-velocity or proper-motion surveys. Such contaminations may lead to a wrong apparent star-formation history of a young cluster. In the case of the ONC the theoretical number of gravitationally bound older low-mass field stars agrees with the number of observed older low-mass stars.

Key words:
open clusters and associations: general - open clusters and association: individual: ONC - stars: kinematics - stars: formation

1 INTRODUCTION

Palla et al. (2005) determined the ages of 84 low-mass ($m \approx 0.4 - 1.0$ M$_\odot$) stars in the Orion Nebula cluster (ONC) from isochrones and lithium depletion. Four of these stars have ages between 10 and 18 Myr, whereas the bulk of all stars have ages below 3 Myr. They conclude that stars in the ONC formed moderatly over a long time period exceeding 10 Myr ending in a sharp peak of star formation. This age spread of stars in the ONC has already been recognised by Isobe & Sesaki (1982), who determined ages from 10^4 yr up to 30 Myr and that low-mass stars in the Orion Nebula region have the same ages as the oldest stars in the Orion association Ia.

This contradicts recent results that the process of star formation is rapid. In the case of the Taurus star forming region Hartmann (2003) has shown that after correcting the sample of stars for possible foreground contamination, the age spread narrows. Also, observations suggest that star formation occurs in only one or two crossing times (Elmegreen 2000) which results in age spreads much smaller than 10 Myr.

Contrary to this, Tan, Krumholz & McKee (2006) present observational and theoretical arguments that rich star clusters requires at least several dynamical time-scales to form and they are quasi-equilibrium structures during their assembly. For the ONC they concluded that it has formed over $\gtrsim$ 3–4 dynamical times.

Indeed, the measurements by Palla et al. (2005) are excellent, comparing ages of stars in the ONC derived with different methods. But the existence of older stars in the ONC must not stringently imply that star formation is an extended process. Given the velocity dispersion of the low-mass stars in the ONC is approximately 2.5 km s^{-1} (Hillenbrand & Hartmann 1998) a star not originating from the ONC can come from a place up to 25 pc away if it is 10 Myr older than the cluster member stars.

In the case of ω Cen ($2.5 \cdot 10^6$ M$_\odot$) Fellhauer, Kroupa & Evans (2006) have shown that a massive stellar super-cluster may trap older galactic field stars during its formation process that are later detectable in the cluster as an apparent population of stars with a very different age and metallicity. Up to about 40% of its initial mass can be additionally gained from trapped disc stars,

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while certain conditions may even lead to such a massive cluster capturing a multiple of its own mass.

Here we show that a collapsing pre-ONC cloud core leads to an enhancement of fore- and background stars and to the capture of some older field stars so that they are gravitationally bound by the new star cluster. Given realistic initial conditions the order of magnitude of the number of captured stars agrees with the number of older low-mass stars in the ONC. These captured older stars have similar radial velocities and proper motions as the newly formed stars in the ONC and can therefore not be distinguished kinematically from the new stars, which will lead to a much wider derived age spread.

2 MODEL

The entire model consists of a collapsing pre-cluster cloud core embedded in a uniform field population of older stars, which — in the case of the ONC — can be a slowly expanding association.

The collapsing pre-cluster cloud core is described by a time-dependent Plummer potential

$$\Phi_{\rm cl}(t) = -M_{\rm cl}\, G\, \left(r^2 + b_{\rm cl}^2(t)\right)^{-\frac{1}{2}} , \qquad (1)$$

where $M_{\rm cl}$ is the constant total mass of the collapsing cloud. The Plummer parameter, $b_{\rm cl}(t)$, is a function of time to describe the growing potential starting with an infinite value and ending with a finite final value within a finite time to account for the ongoing concentration of the pre-cluster cloud core forming a new star cluster.

The background stars are set up in a sphere centred on the origin of the Plummer potential. The positions of the stars are uniformly distributed and their initially isotropic velocities have a Gaussian distribution. Choosing a field-sphere is uncritical as long as its radius is large enough.

In this model the stars do not interact gravitationally. They move as test particles in an external potential. The stellar masses can be eliminated in the equation of motion and the result does not depend on the masses of the stars.

The orbit of the field stars are integrated using a standard Hermite scheme (Makino 1991; Hut et al. 1995; Aarseth 2003). The total energy is used to control the integration. Due to the time-dependent cloud potential the total energy is not conserved. Therefore the path integral,

$$W = \int \boldsymbol{F}_{\rm cl} \cdot {\rm d}\boldsymbol{r} \quad , \qquad (2)$$

of the stars in the force field of the cloud is computed. Given the energies,

$$E_0 = U_0 + T_0 \quad \text{and} \quad E_t = U_t + T_t \quad , \qquad (3)$$

where E_0, U_0 and T_0 are the total, potential and kinetic energies at the initial time t_0 and E_t, U_t and T_t are the total, potential and kinetic energies at an arbitrary time point t, we control the calculations by the total energy error

$$\epsilon = \frac{E_0 - (E_t - W)}{E_0}. \qquad (4)$$

In all simulations the total relative energy error is less than 10^{-11} per particle.

3 INITIAL CONDITIONS

To simulate the capture of stars by the above model, initial conditions for the underlying stellar field population and the collapsing cloud must be specified. In the case of the ONC the stellar background population is given by a postulated surrounding association.

3.1 Collapsing cloud

According to Hillenbrand & Hartmann (1998) the virialized total mass of the ONC is determined to be about 4500 $M_\odot$ while only one half is visible in stellar material. If virialisation of the very young ONC is assumed before gas expulsion has started then the cloud mass, $M_{\rm cl}$, can be set to 4500 $M_\odot$.

The cloud collapse begins at time t_b and ends at t_e after the collapse time, $\tau_{\rm cl}$, has elapsed. For a constant cloud mass the increasing compactness of the collapsing cloud is described by a Plummer parameter of $+\infty$ before the collapse starts and has the constant value b_0 when the collapse finishes. Between these points the Plummer parameter is interpolated simply by

$$b_{\rm cl}(t) = \begin{cases} +\infty & ; \ t < t_b \ , \\ b_0\, \frac{(t_e - t_b)}{t - t_b} & ; \ t_b \leq t \leq t_e \ , \\ b_0 & ; \ t > t_e \ , \end{cases} \qquad (5)$$

where $t_e - t_b$ is the collapse time $\tau_{\rm c}$. Hillenbrand & Hartmann (1998) specify the core radius (projected half-density radius) of the current ONC to lie between 0.16 and 0.21 pc. The actual core radius $r_{\rm c}$ and the Plummer radius b_0 are related by

$$r_{\rm c} = \left(\sqrt{2} - 1\right)^{\frac{1}{2}}\, b_0 \approx 0.64\, b_0 \quad , \qquad (6)$$

which implies a current Plummer radius for the ONC between 0.25 and 0.33 pc. Here we choose $b_0 = 0.30$ pc for the ONC as a mean value.

The collapse time, $\tau_{\rm c}$, of the pre-cluster cloud core is estimated by the free-fall time scale (Elmegreen 2000)

$$t_{\rm ff} \approx \sqrt{\frac{R}{G\, M_{\rm cl}}} \quad . \qquad (7)$$

If the extension of the cloud at the onset of collapse was 1 pc, the corresponding free-fall time is computed to be about 0.22 Myr, in the case of 5 pc as the initial radius the free-fall time-scale is 2.50 Myr and 7.07 Myr for a 10 pc radius. By measuring the offset between HII- and CO-arms in spiral galaxies Egusa et al. (2004) determined the time for star clusters to "hatch" from their natal cluster to be about 5 Myr. Also Weidner, Kroupa & Larsen (2004) conclude from a comparison of star formation rates and maximum cluster masses in a large ensemble of galaxies that pre-cluster cloud cores have radii of about 5 pc if they form in a free fall period. Because the possible collapse time-scale can vary over 2 decades the collapse time $\tau_{\rm c}$ is taken here to vary between 0.1 up and 10.0 Myr.

3.2 Underlying field population

The task to make a specific setup for the underlying field population at the onset of the collapse is far more difficult than for the collapsing cloud. The conditions of the stellar density before collapse have to be estimated. For example, the stellar local mass density of the solar neighbourhood is about 0.1 $M_\odot$ pc^{-3} (Bahcall, Flynn & Gould 1992; Bienayme, Robin & Creze 1987; Kuijken & Gilmore 1989; Kroupa, Tout & Gilmore 1993). In the compiled radial morphology around Θ^1C (Hillenbrand & Hartmann 1998; Herbig & Terndrup 1986) the outermost population (the Orion Ic association) has an extent of more than 25 pc. The embedding cloud Orion A also contains a large number of small groups and a significant distributed population (Megeath et al. 2005; Strom & Strom 1993). The ONC is thus part of a region with low- and high mass star formation in the recent past and at present. So it can be assumed that the stellar density must have been higher at the onset of the pre-cluster cloud collapse than in the solar vicinity. We choose the background as a sphere with a radius of 12.5 pc, corresponding to the extent of the embedding association. 2410 stars distributed in this sphere would give a mean number density of 0.3 stars pc^{-3} or a mass density of 0.1 $M_\odot$ pc^{-3} equal to the mean stellar mass density of the solar vicinity. Here, the number of background particles is rather taken to be 20000 on two grounds: the resulting density, 2.44 stars pc^{-3} or 0.83 $M_\odot$ pc^{-3}, is slightly higher than the density in the solar vicinity and this high number of particles guaranties useful statistical results. These 20000 stars could have been formed e.g. in two ONC-type star clusters.

In fact, the total number of stars within the setup sphere and its radius are not the primary parameters affecting the results, but rather the resulting number density and the initial velocity dispersion. As these stars act as test particles the results can be scaled linearly with the initial uniform density.

For the brightest members of the ONC van Altena et al. (1988) found a one-dimensional velocity dispersion of 1.49 km s^{-1}, while Jones & Walker (1988) specify the velocity dispersion to be slightly larger with 2.34 km s^{-1}. In Hillenbrand & Hartmann (1998) a value of 2.81 for stellar masses between $0.1 < m/M_\odot < 0.3$ and 2.24 km s^{-1} between $1 < m/M_\odot < 3$ is reported. If the underlying stellar background population had a similar progenitor the velocity dispersion can be assumed to be of the same order, i.e. 1$\sim$3 km s^{-1}. Thus we vary the one dimensional initial velocity dispersion of the background sphere from 0.5 (0.87) up to 3 (5.20) km s^{-1} (three dimensional dispersion in parentheses).

Summarising, the choice of the initial background population is a follows: 20000 particles are uniformly distributed over a sphere with a radius of 12.5 pc, giving a stellar density of 2.4 stars pc^{-3}. The particles have a Maxwellian velocity distribution and a random direction. The velocity dispersion, σ, of the different models varies from 0.5 km s^{-1} to 3.0 km s^{-1}. The background sphere and the collapsing cloud have the same velocity centroid.

4 STELLAR CAPTURE

4.1 Number of expected captured stars and the IMF

Palla et al. (2005) selected a sample of 84 stars in the range ≈0.4–1.0 $M_\odot$ and with isochronal ages greater than $\sim$ 1 Myr out of the ONC-survey made by Hillenbrand (1997). This ONC-survey covers 3500 stars within 2.5 pc of the central Trapezium. The low-mass stars of the sample have a membership probability greater than 90 per cent. 6 stars (7.1 per cent) of the sample of 84 stars have isochronal ages $\gtrsim$ 10 Myr, whereas four of them show a significant lithium depletion. The ages derived from the amount of lithium depletion confirm the ages derived from isochronal lines.

To estimate the expected total number of older stars in the ONC this sample must be extrapolated to the entire ONC. The actual total mass of the ONC is given by Hillenbrand & Hartmann (1998) to be about 1800 $M_\odot$. Using the universal or standard/canonical IMF (Kroupa 2001; Weidner & Kroupa 2006; Pflamm-Altenburg & Kroupa 2006) and the "WK-normalisation" method the ONC should have formed 694 low-mass stars in the mass regime 0.4–1.0 $M_\odot$. Note that the "WK-normalisation" refers to the maximum mass of the star being determined by the cluster mass (Weidner & Kroupa 2004, 2006). This determines the normalisation constant of the IMF. Given 6 older stars out of a sample of 84 stars, then 78 stars of this sample should have formed in the ONC. Thus, $6/78 \times 694 \approx 53$ older stars are expected among 694 newly formed stars after linear extrapolation.

4.2 Calculated number of captured stars

After the collapse time τ_c, when the collapse has stopped, then a star is identified to be captured by the collapsed cloud if the star is gravitationally bound and lies within a 2.5 pc radius of the centre of the potential, according to the extend of the ONC-survey by Hillenbrand (1997): after the collapse stops the distance of the star to the origin of the Plummer sphere is less than 2.5 pc and the total energy of the stars is less than required to get farther away than 2.5 pc from the centre of the potential. This means that a captured star is gravitationally bound to the new cluster. As the virial mass of the current ONC is about 4500 $M_\odot$ but only one half is visible in stellar material (Hillenbrand & Hartmann 1998), the ONC is super-virial (kinematically too hot). This can be solved if the ONC is expanding after gas expulsion (Kroupa, Petr & McCaughrean 1999; Kroupa, Aarseth & Hurley 2001). The whole cluster is expected to have been virialized between the stop of the pre-cluster cloud core collapse and the start of gas expulsion. After gas expulsion the older captured stars follow the dynamical evolution of the young star cluster. So it is justified to identify a captured star by the criterion that it be gravitationally bound to the collapsed cloud when the collapse of the pre-cluster cloud core stops.

The number of captured stars in dependence of the collapse time-scale, τ_c, can be seen in Fig. 1. The initial stellar density is 2.44 stars/pc^3 implying a total number of stars placed initially within a 2.5 pc radius around the centre of the potential of 160 (Section 3.2). A decreasing collapse time means that the time-dependent period becomes shorter and the potential behaves increasingly as an instantaneously switched on potential. Therefore only those stars being initially within the 2.5 pc sphere can be captured for short τ_c. Out of these candidates only that fraction of stars is captured having a velocity less than a certain limit. Thus the models with the shortest collapse time of 0.1 Myr con-

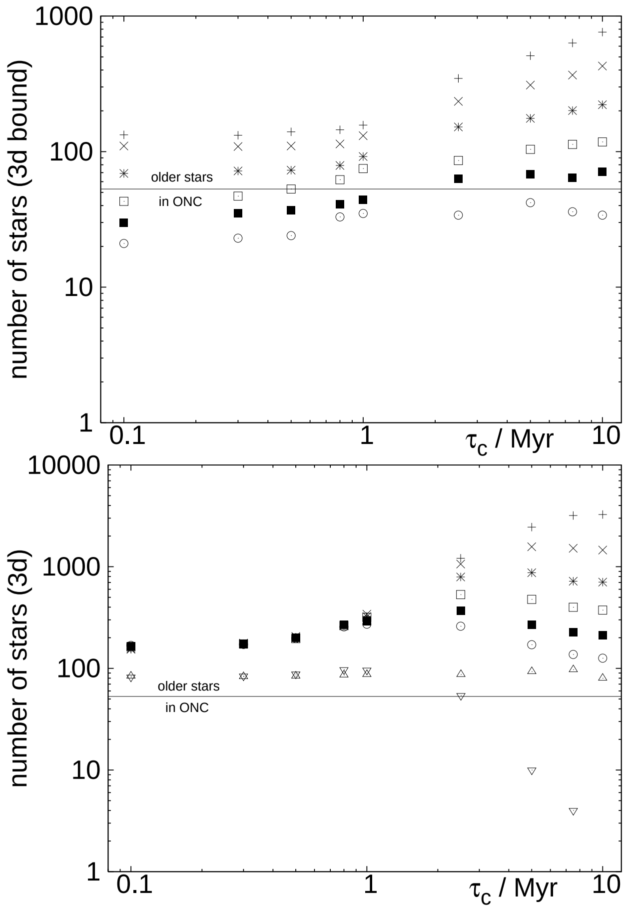

Figure 1. Number of stars within 2.5 pc of the centre after the collapse time-scale, τ_c, has elapsed and the collapse stops.
Top: Number of stars within 2.5 pc of the centre of the potential *and* gravitationally bound. *Bottom*: Number of stars within 2.5 pc of the centre of the potential. *Symbols*: Models with a one-dimensional velocity dispersion, σ, of the background field in presence of the collapsing cloud: $\sigma = 0.5$ km s^{-1} (+), 1.0 km s^{-1} (×), 1.5 km s^{-1} (∗), 2.0 km s^{-1} (□), 2.5 km s^{-1} (■), 3.0 km s^{-1} (○). The open triangles denote the number of stars within 2.5 pc radius of the centre of the background sphere with time if *no* cloud potential is present for two different field-star velocity dispersions: $\sigma = 0.5$ km s^{-1} (△) and 3.0 km s^{-1} (▽). The horizontal line marks the region of the 53 expected older low-mass stars in the ONC. For details see text.

verge against the initial star number of 157 with decreasing field-star velocity dispersion (Fig. 1, top). With increasing collapse-time more stars are able to move inwards loosing energy in the time-dependent potential and the number of captured stars increases. In the case of the highest field-star velocity dispersion the number of captured stars turns over at large collapse times because the potential is very low initially for a longer period. The diffusion of the background sphere then dominates over orbit focussing by the increasing potential.

To compare the number of captured stars calculated in these simulations with the number expected it has to be taken into account that the test particles forming the background sphere represent a realistic stellar population having a mass spectrum. Given a canonical IMF 13.5 per cent of all stars lie in the mass regime 0.4–1.0 M$_\odot$. For the preferential value of the collapse time of 5 Myr the number of captured stars is 42 (510) if the velocity dispersion of the background sphere is 3.0 (0.5) km s^{-1}, resulting in 6 (69) captured low-mass stars.

Given its age of about 1 Myr the ONC is already dynamically evolved and has expelled its gas almost completely. Its virial mass of about 4500 M$_\odot$ is more than twice larger than the stellar mass. Being nearly virialized at its formation the ONC has already started to expand implying that its concentration must have been larger initially and its describing Plummer parameter b_0 must have been smaller than 0.3 pc, when cloud collapse has stopped. This has been confirmed by numerical simulations (Kroupa et al. 2001). Thus the potential would have been deeper than assumed in the present calculation, and the number of captured stars would be higher than determined here.

Therefore, the existence of older stars in the ONC does not necessarily imply that star formation is prolonged – dynamical capture can explain the presence of older stars in the ONC and in young star clusters in general.

From the dynamical point of view these gravitationally bound stars are true cluster members. It is not a question of measurement accuracy that these stars are identified to be cluster members. So even GAIA can not distinguish between the older stars captured by cloud collapse and the stars formed in the young star cluster, although on average the captured stars would have a flatter density profile than the stars formed in the cluster (Fellhauer et al. 2006).

As the membership probability of the sample of low-mass stars in the ONC, selected by Palla et al. (2005), is greater than 90 per cent but not 100 per cent, based on proper motion and radial velocity studies, it is possible that these older stars (or some of them) are part of the fore- and background contamination. But independently of the true origin of these older stars, stellar capture during pre-cluster cloud collapse must be a true physical process and older stars among newly formed stars in a young star cluster should exist.

5 ENHANCEMENT OF STELLAR DENSITY

In the previous section only those stars were considered which are gravitationally bound. These constitute a fraction of all those field-stars which are deflected from their initial orbit and are focussed towards the centre of the cluster. In general, the density of the field-stars will deviate from their constant initial density in two ways.

5.1 Slowed-down dilution of an OB association

In absence of a collapsing pre-cloud cluster core the OB association will disperse due to its internal velocity dispersion. In presence of such a collapsing cloud the stars are increasingly attracted towards the centre of the newly formed cluster. Therefore the field-star density near the cluster centre will be kept higher during the cluster formation than in absence of the cluster potential. In the case of a collapse-time of 5 Myr and a field-star velocity dispersion of 3 km s^{-1} the number of stars within 2.5 pc of the centre of the background sphere is 108 (with cloud collapse) and 10 (without cloud collapse) when the collapse stops. This means that the field-star density will be kept higher by a factor of 10 due to the attracting potential by the collapsing cloud (Fig. 1, bottom).

5.2 Underestimation of background subtraction

When the pre-cluster cloud becomes increasingly compact then the radial dependence of its potential increases. The density of the field-stars is expected to show a similar dependence, getting higher towards to the cluster centre. The corresponding ratios of the field-star densities in the newly formed cluster and the cluster vicinity are plotted in Fig. 2. After the collapse has stopped the cluster density, ρ_c, is calculated by the number of field stars within 2.5 pc radius of the cluster centre. The density of the field-stars, ρ_{sh}, in the cluster vicinity is calculated by the number of stars within the shell limited by the radii of 10.0 and 7.5 pc. For a collapse time of 5 Myr and a field-star velocity dispersion of 3 km s^{-1} the density of the field-star in the new cluster is almost 10 times higher than in the vicinity of the cluster. This has to be taken into account when surveys of star clusters are corrected by the fore- and background contamination.

In general three tendencies can be seen. i)The density contrast increases with an increasing collapse-time. ii) For a constant collapse time the density contrast increases with an increasing initial velocity dispersion of the background population. iii) With increasing collapse-time the final density ratios for different initial velocity dispersions are less different.

The behaviour of the data in Fig. 2 can be understood by noting the following: If the full potential would be switched on instantaneously then the density contrast would be unity. With an increasing collapse-time more stars can move towards the cluster centre and the density contrast increases. Within a constant collapse-time more stars can move towards the cluster centre if the initial velocity dispersion is higher.

6 DISCUSSION

As the region, where the ONC lies in, is a location of high star formation, the initial conditions prior to pre-cluster cloud collapse, i.e. the stellar density and distribution, are difficult to estimate. If the older ONC stars have not formed in the ONC as a result of prolonged star formation then where could they have formed?

Given the age of the association Orion OB1c surrounding the ONC of about 4.6 Myr (Brown et al. 1994) the observed older stars in the ONC, having an age greater than 10 Myr, can not have formed in the parent cluster of this association.

The association Orion OB1a has an age of approximately 11 Myr. The projected distance from its centre to the ONC is of about 5 degrees, i.e. 35 pc given a mean distance of 400 pc of both associations. The line-of-sight distance between Orion OB1a and the ONC is approximately 117 pc (Brown et al. 1999). Then the probably captured low-mass stars, if formed in the association Orion OB1a, must have had a spatial velocity of 12 km s^{-1} relative to the centre of the ONC for them to have drifted to the current distance of the ONC. If the time-scale of the pre-cloud core collapse is

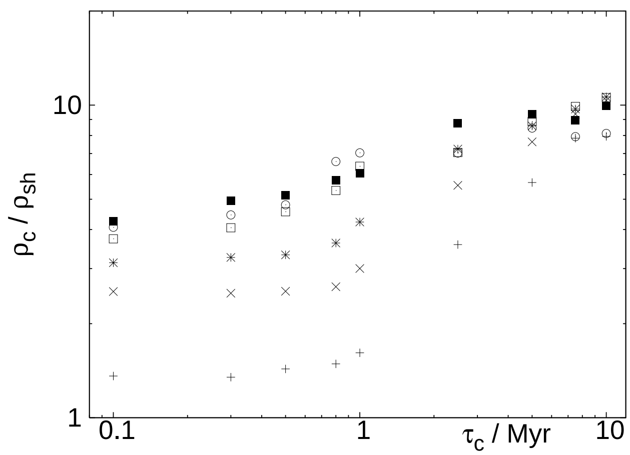

Figure 2. Ratio of the field-star density in the cluster, ρ_c, and in the vicinity of the cluster, ρ_{sh}, after the collapse has stopped. *Density in the cluster*: Number of stars within 2.5 pc radius of the cluster centre divided by the volume of the sphere. *Density in the vicinity*: Number of stars in the shell between 10 and 7.5 pc divided by the volume of the shell. *Symbols*: Models with a one-dimensional velocity dispersion, σ, of the background field in presence of the collapsing cloud: $\sigma = 0.5$ km s^{-1} (+), 1.0 km s^{-1} (×), 1.5 km s^{-1} (∗), 2.0 km s^{-1} (□), 2.5 km s^{-1} (■), 3.0 km s^{-1} (○).

taken into account the velocity must be even higher. Stars from such a population would not have been captured. Additionally, Brown et al. (1999) listed 61 OB stars for the Orion OB1a association. Given a canonical IMF the parent cluster should have contained about 3150 M$_\odot$ in stars and therefore 1100 stars between 0.4 and 1.0 M$_\odot$. If all these low-mass stars are completely radially dispersed during the expansion of the OB-association the stellar flux at the ONC would have been 6×10^{-3} stars/pc^2. Given a radius of 2.5 pc of the ONC then 0.5 stars with masses between 0.4 and 1.0 M$_\odot$ have passed through the ONC, too few compared to the estimated number of older low-mass stars of 53. It seems to be unlikely that these older stars have formed in Orion OB1a, although its age would be consistent with this.

The nearer association Orion OB 1b has an age of 1.7 Myr (Brown et al. 1994). This is contrary to the ages determined by Blaauw (1991) (7 Myr) and by Warren & Hesser (1978) (5.1 Myr). Nevertheless, it can be concluded that Orion OB 1b might be too young to be the origin of the older stars in the ONC.

The compact ONC has 3500 stars within a radius of 2.5 pc around Θ^1 C (Hillenbrand 1997), giving a number density of 528 stars pc^{-3}. As the current ONC has an age of approximately 1 Myr it is already dynamically evolved. Using full N-body simulations including gas expulsion Kroupa, Aarseth & Hurley (2001) have shown that initially the ONC may have contained approximately 10^4 stars and brown dwarfs to match its current state. This means that the ONC has already lost 65 per cent of stars. To get 20000 stars within a sphere of 25 pc in diameter 2 ONC-type cluster are required. This huge amount of past star formation should still be observable in terms of an association. At least the $2 \times 39 = 78$ O-stars, given a canonical IMF, should still be visible. Given the live time of a 20 M$_\odot$ star of approximately 9.9 Myr (Schaerer et al. 1993), then $2 \times 10 = 20$

supernovae should have occurred, where 10 $m \geq 20$ $M_\odot$ stars occur in a population of 39 $m \geq$ $M_\odot$ stars. Reducing the radius of the background sphere to 9.9 pc then only 10000 stars or one ONC-type star cluster would be required to keep the initial stellar density of 2.4 stars/pc^3. Using a canonical IMF the mass of a star cluster must be less than 160 $M_\odot$ to contain less than 1 O star. Nearly 20 such low-mass clusters are required to produce 2×10^4 stars in total. If the background sphere had only a radius of 9.9 pc then only 10 such low-mass clusters are needed to form the initial background density. If these low-mass clusters formed more than 10 Myr ago, then they are not expected to be still visible, as such small star clusters disperse rapidly. Also, many of these older stars should be mixed up with the ONC.

However, our results do not exclude the possibility that the ONC formed over about 3 Myr, i.e. a few free-fall times (Tan et al. 2006). The important time scale for the effects described here is the time scale of potential formation and not the time scale of star formation.

Possibly, the most likely source of the older low-mass star population might be a large number of small groups producing low-mass stars as are also observed today but only 10 Myr earlier (Megeath et al. 2005). For example, Kroupa & Bouvier (2003) have shown that small Taurus-Auriga-type groups disperse on a time scale of a few Myr.

In our initial conditions it is assumed that the ONC and the background sphere have the same velocity centroid. If the relative velocity between the background sphere and the collapsing pre-cluster cloud core increases then fewer stars are expected to be captured. But the pre-cluster cloud core of the ONC as well as the earlier star clusters or groups, which formed the background stars, may have formed within the same molecular cloud. So a relative velocity between the different velocity centroids may have been small.

The increasing potential of the collapsing pre-cluster cloud core should not only act on already formed stars but also on protostars. Applying the results of the enhancement of the background density on the stellar population in the molecular cloud Orion A the mean motion of the young stars and the protostars should be directed towards the centre of the ONC, being more pronounced in the region of the cloud nearest to the ONC.

7 CONCLUSIONS

We have shown that the existence of older stars in the ONC must not necessarily imply that star formation was prolonged in the ONC. The time-dependent potential of a collapsing cloud can capture older stars of the underlying OB association. These stars exhibit similar kinematical properties leading to their identification as cluster members. The number of captured stars is in agreement with the number of observed older low-mass stars for reasonable assumptions about the pre-existing field-star population. Nevertheless, some open issues concerning the origin of the field-star population remain.

Additionally, the increasing potential of the collapsing cloud leads to an enhancement of the local stellar background density causing larger fore- and background contamination.

The number of captured stars and the amount of fore- and background enhancement significantly depend on the deepness of the final potential when the cloud collapse stops. Therefore these effects should be more distinctive for more compact and more massive star clusters (Fellhauer et al. 2006).

Moreover, the number of capture stars and the number of focussed but not captured stars depend on the surrounding density of the field stars. Therefore the number of older stars found in young star clusters that are part of a greater star-formation region and/ or are embedded in an OB association should be higher than in young star clusters formed in isolation.

We conclude that the apparent long formation time of young star clusters may be brought into agreement with the recent notion that the formation of clusters is a highly dynamic and violent process by taken into account that the short formation process leads to stellar capture from an underlying older field population. This process depends on the time-scale of cluster potential formation, the velocity dispersion and density of the field population.

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